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be truly said that the highest estimate of his moral excellence was formed by those who were brought into closest intercourse with him.

President Woolsey lived for eighteen years after he retired from the position of head of the College. His closing days were clouded with infirmities. He died on the 1st of July, 1889.

FOREIGN HONORARY MEMBER.

JAMES PRESCOTT JOULE.

JAMES PRESCOTT JOULE was born at Salford, near Manchester, England, on December 25, 1818, the second of five children. As a lad he was so delicate that he was not sent to school, but was taught at home by tutors until he was about fifteen years of age, when he began to work in his father's brewery; and when the health of the father declined, the business fell entirely into the hands of young Joule and his brother Benjamin. The business made some knowledge of chemistry a necessity, and the two brothers were sent to Dalton, one of the most distinguished chemists that ever lived, to acquire it. Dalton at that time was President of the Manchester Literary and Philosophical Society, living and taking pupils at the Society's house in Manchester. The boys were taught arithmetic, algebra, and geometry at first, and afterwards natural philosophy and chemistry. For a text-book in chemistry Dalton used his own "New System of Chemical Philosophy." In 1837 Dalton's health became impaired so that he no longer received pupils, and it does not appear that Joule had any further school instruction. Dalton had introduced to his pupil physical and chemical apparatus, and had evidently taught him in some degree the art of experimentation. It is evident, too, that Joule was an apt scholar in that direction, for he at once began to experiment on his own account. He appropriated a room in his father's house, and enlarged his stock of apparatus mostly by his own constructions. There he began, in 1838, before he was twenty years of age, a series of investigations continued through his life, which for ingenuity, thoroughness, and scientific importance have not been exceeded by any one in this century. About an hundred titles of papers by him alone are on the list of the Royal Society of Great Britain, and twenty in conjunction with Thomson, Playfair, and Scoresby.

A distinguishing feature of the whole of Joule's work is his aim for quantitative results. His first work appears to have been upon

electro-magnetic engines, and his description of the mechanism and of its performance, as given in Sturgeon's "Annals of Electricity" in 1838 and after, show the definiteness of his ideas and of his work. For instance he tells how many grains his electro-magnets weighed, how many yards of silk-covered copper wire one fortieth of an inch in diameter were wound upon them, how many grains each magnet would hold up, how many revolutions per minute his engine made when supplied with electricity by one or more cells of battery, and how many pounds it was capable of raising one foot in a minute. Such painstaking to know the value and importance of every step in an inquiry is rare to-day, but it was much rarer fifty years ago; and to be found in a youth of twenty years, having no supervision and no incentive beyond his own impulses, is surprising indeed.

It is to be borne in mind, that in those days the so-called various forces, heat, light, electricity, magnetism, and chemism, were supposed to be independent forces; the idea of correlation among them had not dawned among physicists; much less had they any conception of what we call to-day the conservation of energy, which implies that all the various forms of energy are not only transformable into one another, but that they are so related quantitatively that the appearance of a definite quantity of one kind of energy implies the disappearance of an equal quantity of some other kind. Faraday indeed had already shown such a relation between chemism and electricity. Beyond that there was nothing done, and there were no fundamental ideas such as we to-day start with. When, therefore, we find young Joule measuring the work done by an electric motor in foot pounds, and comparing the result with the amount of zinc dissolved in his battery, it is easy to see how far ahead of his contemporaries he was. From his experiments with batteries and his electro-magnetic engines in 1839 and 1840, he concludes that galvanic batteries using zinc cannot be made to compete with steam-engines using coal as sources of power. His conclusions still hold good after the lapse of fifty years, and the experience of a multitude of experimenters, some of whom continue to work and hope that the laws involved are not so rigorous as Joule supposed.

In 1841 he discovered that a bar of iron was elongated when it was magnetized, and he measured the amount of the elongation, finding it to be the one thirty-thousandth part of an inch in a bar two feet long when magnetized with the current from five Grove cells.

In 1840 he presented a paper to the Royal Society containing an investigation into the distribution of heat in an electric circuit, wherein

he concludes that the heat produced is proportional to the resistance of the conductor, independent of the shape or kind of metal which closes the circuit. He proved also that the "heat evolved in a given time is proportional to the resistance of the conductor multiplied by the square of the electric intensity." By electric intensity he meant what we now call current, and the above we now recognize as RC^2 .

In the early part of the century, Davy and Count Rumford had proved from their experiments that heat was but a kind of molecular motion, not an entity as had long been supposed, but this conception did not become general among those who had most to do with thermal phenomena. Text-books, as well as special treatises, continued to represent the old conceptions as yet valid till within about twenty-five years. Nowadays we are so familiar with the expression "heat as a mode of motion" that few give to it more than a passing thought, and a large number of persons who deal with the subject of heat in its mechanical relations speak of it as a "form of energy," an expression which fails to convey with any definiteness the character of the motions that differentiate heat from other kinds of energy motion. As energy is a product with motion as one of the factors, it follows that a *mode of motion* and a *form of energy* cannot be identical. Joule was not muddled on that. In 1843 he read a paper before the British Association on the "Mechanical Value of Heat." In that paper he says, "When we consider heat not as a *substance*, but as a *state of vibration*, there appears to be no reason why it should not be induced by an action of a simply mechanical character." The Italics are his. He then describes at length numerous experiments in which the heat developed in an electric circuit was measured, when the electric current was produced by a magneto-electric machine. The amount of work required to turn the magneto-electric machine when producing the current was carefully measured also, and from these he reached the first determination of the mechanical equivalent of heat, namely. "*The quantity of heat capable of increasing the temperature of a pound of water by one degree of Fahrenheit's scale is equal to, and may be converted into, a mechanical force capable of raising 838 pounds to the perpendicular height of one foot.*" This result, as we now know, is too large, and in 1881 he accounted for the excess by noting that no allowance was made for the heat absorbed by the magnet itself, which at first he thought neglectable; but at the latter date he concludes it would account for all the difference between 838 and 772.

The story of the reception of this remarkable paper by British physicists, giving as it did the first law of thermodynamics, is strik-

ing. It was read before the Chemical Section of the British Association Meeting at Cork, on the 21st of August, 1843. Some of the members of the Royal Society expressed the opinion that it was nonsense from beginning to end, that the author must live in some benighted region, that the imponderables could not be expressed in foot pounds, etc., and as a body they refused to publish it in their Transactions. Sir William Thomson in 1847, though not entirely persuaded of the truth of Joule's conclusions, seems to have been the only one to show any degree of friendliness to them, and he advised moderation in the condemnation; nevertheless, the paper was not published by the Society until 1850, seven years after its presentation.*

Sir H. E. Roscoe said, when referring to the reception of this epoch-making paper of 1843, that "the men who so bitterly opposed it ought to have known better." But it is certain that they had been taught differently, and when one has achieved distinction in physical science he is likely to possess his own philosophy of things, in which not a small part of the data is symbolic, and is represented in mind only by a name, and if this name chances to suggest something mysterious, as, for instance, an imponderable, the less is one likely to attempt or suffer others to attempt to displace it by definite mechanical conceptions. To change one's fundamental conceptions necessitates a change in his philosophy,—a change that is not only difficult, but highly distasteful, to everybody; hence one could hardly expect much of a welcome to a man whose work demanded such a change; and this was the case with Joule, as it was with Galileo, with Newton, with Laplace, Young, and Faraday.

His inquiries thus far had led him to the examination of the quantitative relations not only existing between heat and so-called mechanical motion, but also those existing between chemical affinities, electricity, and magnetism,—in fact, between all the forms of energy in inorganic phenomena; and for these he was able to show a mechanical equivalent, in such a way as to make it certain that the only difference between the so-called forces of those days was a difference in the character of the motions the bodies that exhibited the forces had. In this body, all the molecules are moving in one direction at a certain rate, and we call it mechanical motion. In another body, the molecules are individually vibrating while the body as a whole does

* In 1849 he presented a paper to the British Association upon the same subject, which was printed, except the following proposition, which the committee was unwilling to publish. "Friction consists in the conversion of mechanical power into heat." (!)

not change its position, and this we call heat; but when the sum of the individual motions is equal to the motions of the first body, the two bodies have the same amount of energy. One condition we call mechanical, the other heat. In a proper sense they may all be called mechanical conditions, but it is convenient to designate the varieties by different names. Joule evidently saw this at the outset, for his experiments were all devised to fit such hypothetical conditions, and they therefore show how clear his mechanical conceptions were, and how far in advance he was of any of his contemporaries.

His experiments upon the mechanical equivalent of heat were continued from year to year for a long time. In 1847 he had reduced the equivalent to 781.8, and in 1849 to 772 foot pounds, the same number we use to-day. He followed out the fundamental idea in all sorts of ingenious ways; by friction in water, in oil, in mercury, in the velocity of sound in air, in determining the velocity of a molecule of hydrogen under standard conditions of temperature and pressure, in calculating specific heats, in the efficiency of steam and air engines, the effects of pressure, and the temperature of meteors while passing through the atmosphere. By 1852, however, Joule's work became pretty generally known in Europe, and he had been elected a member of numerous societies there before he had been thus honored at home. It was the old story. The wise man lives in the next town, he is not our neighbor. While the learned of Europe were honoring him, the people of Manchester were asking, "Who is this Joule of Manchester we are hearing about?"

In 1864 he was made one of the Committee of the British Association to devise a system of electrical units, which gave us the volt, the ohm, and the rest of the unit terminology so indispensable now. In his earliest work, it was necessary for him to know with greater definiteness than was possible with such a system as was then in use, or rather the lack of it, and he devised one which is easily transformed into the absolute one we now employ, and his services in that committee were invaluable. The determination of the ohm resulted in a larger figure for the mechanical equivalent of heat than Joule had found in other ways, and he offered to change its value to correspond; but it afterwards appeared that his value was nearer right than the new one thus obtained. In 1878 his determination of this quantity was 772.55 pounds. This mechanical equivalent is sometimes called a Joule, and has J for its symbol in honor of the discoverer.

The statement of the relationship between heat and work is the

first law of thermodynamics and is framed in various ways by different authors.

Joule was married in 1847, but his wife died in 1854, leaving him a son and a daughter.

As to his character it appears that he was not a public man. He had but few acquaintances. His interests were with his apparatus in his laboratory. He had a rare way of interrogating Nature, so that her answers were not enigmatical, as they often are to less gifted men. The outcome of his work is of such a character as to quite transform all our conceptions of the order and precedence of things physical in the heavens and in the earth. It has given us the new and fundamental science of thermodynamics, and has necessitated the rewriting of all philosophy.

The Physical Society of London has published a collected edition of his works. In 1878 he was granted a pension of £200 per year, and he also received several gold medals in recognition of his labors. He died on October 11, 1889. Steps were taken at once to raise a national memorial to him in the city of Manchester.

The Academy has received an accession of twelve members, — four Resident Fellows, seven Associate Fellows, and one Foreign Honorary Member.

Two Resident Fellows have been elected to fill vacancies in the list of Associate Fellows, and two Resident Fellows have resigned.

The roll of the Academy, corrected to February 15, 1891, includes the names of 186 Resident Fellows, 93 Associate Fellows, and 74 Foreign Honorary Members.